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ANATOMIC BASES OF MEDICAL, RADIOLOGICAL AND SURGICAL TECHNIQUES

Anatomy and external landmarks of the superficial temporal artery using 3-dimensional computed tomography

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Abstract

Purpose The purpose of this study was to analyze the anatomical variability of the superficial temporal artery (STA) and to provide an easy visual landmark to find the STA and its branches to facilitate its surgical access.

Methods A retrospective study was conducted on 57 patients who underwent a head and neck computed tomography with contrast injection. A visual landmark running from the tragus to the corner of the eye was used: the "eye-tragus-line" (ETL). On the ETL, the distance between the tragus and the STA was measured. The length of the STA main branch, its parietal and frontal branch and the angle of the STA and its branches with the ETL were measured. The division of the STA was studied as above/at the same level/below the zygomatic arch (ZA) and the ETL.

Results The STA division was located above the ZA in 61.54% of cases, at the same level in 26.92% of cases and below in 11.54% of cases. Regarding the ETL, 93.27% of the STA divisions were located above the ETL, 5.77% at the same level and 0.96% below. On the ETL, the STA was located 15.55 ± 4.5 mm in front of the tragus.

Conclusion This study allowed to define an easy visual landmark: the ETL running from the tragus to the corner of the eye. The STA main branch was located 15.55 ± 4.5 mm of front of the tragus on the ETL. The STA division was nearly always located above the ETL (99.04%). Furthermore, this study provides a statistical representation of the anatomy of the STA and its branches.

Keywords Anatomy · Temporal arteries · Anatomic landmarks · External landmark

Introduction

The superficial temporal artery (STA) is a terminal branch of the external carotid artery arising behind the mandibular branch within the parotid gland and then crossing the zygomatic arch (ZA). The STA usually divides into two branches supplying a large area of the scalp and forehead skin: an anterior frontal branch and a posterior parietal branch [2, 11, 15]. Anatomical variations exists, consisting mainly in supplementary branches [11].

The localization of the STA is crucial for the planning of surgical procedures such as temporoparietal fascia flap where blood supply is provided by the STA. Temporoparietal fascia locoregional flap is used in various indications in head and neck reconstructions such as reconstructive surgery of the ear and the orbit [1, 3, 9, 16]. It can also be used as a free flap to prevent or treat fistulas by covering defects, for example in oncologic neck surgery [1, 3]. Furthermore, the localization of the STA is important for the diagnosis of giant cell arteritis (GCA), a vasculitis of unknown etiology. The diagnostic of GCA usually requires a biopsy during which STA millimetric branches [6, 13] can be clinically hard to find. Furthermore, the pulsations of the STA branches are sometimes difficult to perceive due to vessel inflammation. The diagnosis of GCA can also be made by ultrasound, which also requires anatomical knowledge of the STA and its branches [7, 12, 13]. In addition, GCA is a rare disease (15–30/100.000 patients over the age of 50 years) [5], and most practitioners are usually unfamiliar and inexperienced with GCA and the STA anatomy.

Currently, the anatomy of the STA and its branches is mainly described from a surgical point of view [2, 10, 11, 14], however its external clinical description is not well

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established. This study therefore aimed to analyze the anatomical variability of the STA and provide external landmarks to facilitate its surgical access. The "eye-tragus-line" (ETL), running from the tragus to the corner of the eye, is introduced as an easy anatomical landmark to find the STA and its branches. This article also described the general anatomy of the STA and its variances. Furthermore, schematic views of the anatomy of the STA were provided, reflecting the areas were the STA and its branches are the most likely to be found. These schematic views can help the clinician, the sonographer and surgeon in finding the STA and its branches whether for clinical examination, ultrasound or planning of surgical biopsies.

Materials and methods

This study was approved by the ethical committee of the CHU UCL Namur, Yvoir (Catholic University of Louvain, B039201835890).

Patients

A retrospective study was conducted on 61 patients who underwent a head and neck computed tomography (CT) with contrast injection at an arterial phase from September 2017 to December 2017. The purpose of those CT were mainly cerebrovascular accidents.

Imaging

The images were obtained using an iCT Elite 256 Phillips CT (Phillips Healthcare, Cleveland, OH, USA) and acquired in arterial phase after an intravenous injection of 60 cc of contrast media (Ultravist; Schering AG; Berlin, Germany) at 4 cc/s. The acquisition was started using a bolus tracking technique with a region of interest positioned in the aortic arch.

Variables studied

The anatomical distribution of both left and right superficial temporal arteries and their branches was studied. The distances and angles were measured on tridimentionnal CT (3D CT) reconstructions (IntelliSpace Portal 8.0, Philips Healthcare, Best, Netherlands).

A new visual landmark was used: the line between the tragus and the eye corner which we called the "eye-tragus-line" (ETL). The distance between the ETL and the STA division was measured on a line perpendicular to the ETL. The angles between the ETL and the STA and its branches were measured as shown in Fig. 1. The distance between the tragus and the STA main branch was measured on the ETL.

As already done in other studies, ZA was used as an anatomical landmark [4, 8, 11, 14, 15]. The topography of the division of the STA was studied in relation to the ZA and the ETL and characterized as above, at the same level or below. The distance between the division of the STA and the superior margin of the ZA was measured on a line perpendicular to the superior margin of the ZA.

The length of each branch of the STA was measured taken as a straight line from the origin of the vessel to the last point of its visibility on the 3D reconstruction.

The presence of supplementary branches was quantified, their origin (from the parietal or frontal branch) was indicated.

The studied variables are summarized in Table 1.

Statistical method

Quantitative variables were described with their mean $\pm$ standard deviation (SD), range and median. Qualitative measures were described using their frequencies and percentages. The R 3.5.2 software (R Foundation for Statistical Computing, Vienna, Austria, 2018) was used with *ggplot2* package for the graphics and *HDIntervals* package for the determination of highest probability density areas.

Results

Population studied

Of the 61 patients selected, 4 were excluded due to insufficient image quality (movement artifacts or poor contrast enhancement). Finally, 57 patients were included in this retrospective study, for a total of 114 STA (Fig. 2). Figure 2 also shows the cases excluded for each variable.

On 57 patients included, 22 patients were women (38.6%) and 35 patients were men (61.4%). The mean age of the patients was 64.7 $\pm$ 12.4 years, ranging from 27–84 years old.

Main STA branch and division point

On the ETL, the distance between the tragus and the STA was measured at 15.55 $\pm$ 4.5 mm (mean value $\pm$ 1 SD) for a median of 16. The exact location of the STA division could not be demonstrated for 10 cases, mainly due to the fact that one the STA branches was occluded. The topography of the division of the STA was located below the ZA in 12 cases (11.54% of 104 STA), at the same level in 28 cases (26.92%) and above in 64 cases (61.54%). Concerning the ETL, the topography of the division of the STA was located below the ETL on 1 case (0.96% of 104 STA), at the same level in 6 cases (5.77%) and above in 97

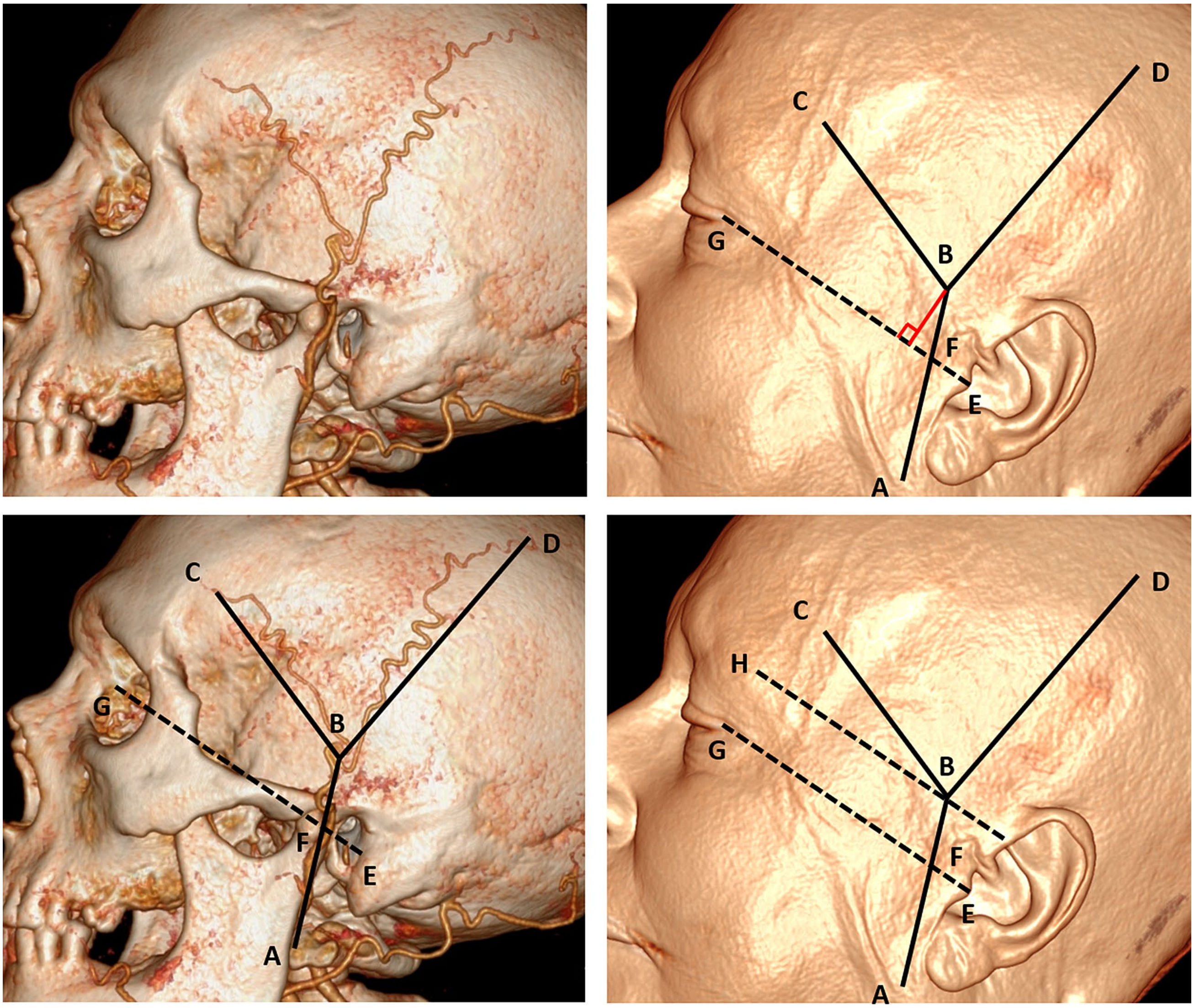

Fig.1 Measures of the lengths and angles of the STA and its branches. *AB* STA main branch, *BC* frontal branch length, *BD* parietal branch length, *EG* eye-tragus-line (ETL), *EF* distance from the tragus to the STA on the ETL, *BH* line parallel to the ETL, *AFG* angle between the STA main branch and the ETL, *HBC* angle between the STA frontal branch and the ETL, *HBD* angle between the STA parietal branch and the ETL, *Red line* Distance between the ETL and the STA division on a line perpendicular to the ETL, *ETL* eye-tragus-line, *STA* superficial temporal artery

cases (93.27%). These results are summarized in Table 2. Other variables are summarized in Table 3.

The distance between the division and the ZA ranged from 0–47 mm with a mean value of 12.31 ± 12.83 mm and a median distance of 8.5 mm. The distance between the division and the ETL ranged from 0–53 mm with a mean of 18.9 ± 12.80 mm and a median of 16 mm.

The angle between the main STA branch and the ETL ranged from 75°–140° with a mean of 109.21° ± 11.08° and a median of 109°.

Frontal branch

The full length and the angle of the frontal branch were not measurable in 22 and 17 cases, respectively. This was mainly due to an insufficient field of view or an occlusion of the frontal branch (Fig. 2). The length of the frontal branch ranged from 23 to 101 mm with a mean of 58.11 ± 16.9 mm and a median of 60.5 mm. Its angle with the ETL ranged from 0° to 60° with a mean of 27.93° ± 12.22° and a median of 28°.

Table 1 Variables studied

STA main branch	
Distance from the STA main branch to the tragus on the ETL	
Angle with ETL	
Division of the STA	
Topography of the STA division in relation to the ZA: above, same level or below	
Topography of the STA division in relation to the ETL: above, same level or below	
Distance between the division of the STA and the superior margin of the ZA measured on a line perpendicular to the superior margin of the ZA	
Distance between the division of the STA and the ETL measured on a line perpendicular to the ETL	
STA frontal branch	
Length	
Angle with the ETL	
STA parietal branch	
Length	
Angle with the ETL	
Other branch(es)	
Number of other branches	
Origin: frontal or parietal branch	
Length	

ETL Eye-Tragus-Line, *STA* Superficial Temporal Artery, *ZA* Zygomatic Arch

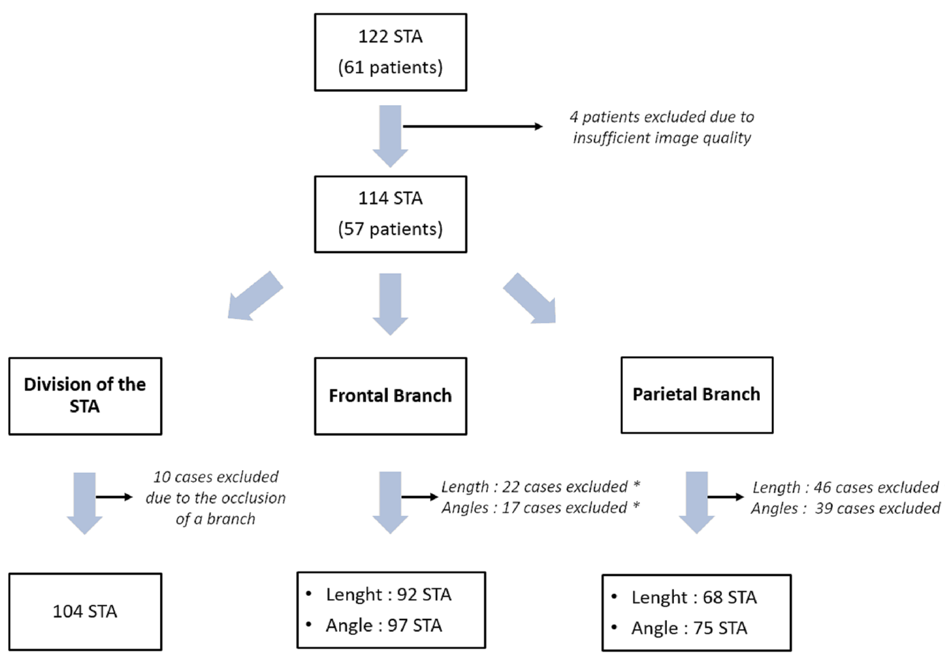

Fig.2 Patients selection Flowchart. *patients excluded due to vessel occlusion or insufficient field of view. *STA* superficial temporal artery

Table 2 Topography of the STA bifurcation regarding to the ZA and the ETL

	ZA % ($n = 104$)	ETL % ($n = 104$)
Above	61.54 (64)	93.27 (97)
Same level	26.92 (28)	5.77 (6)
Below	11.54 (12)	0.96 (1)

ETL Eye-Tragus-Line, *STA* Superficial Temporal Artery, *ZA* Zygomatic Arch

Parietal branch

The full length and the angle of the parietal branch were not measurable in 46 and 39 cases, respectively. This was mainly due to an insufficient field of view or an occlusion of the parietal branch (Fig. 2). The length of the parietal branch ranged from 20 to 100 mm with a mean value of 54.01 ± 16.34 mm and a median of 53 mm. Its

Table 3 Mean distances and angles with Standard Deviation and Median values of the variables studied

	Mean	Standard deviation	Median	Minimum value	Maximum value	n^a
Length (mm)						
Frontal Branch	58.11	16.9	60.5	23	101	92
Parietal branch	54.01	16.34	53	20	100	68
Distance (mm)						
From the tragus to the STA on the ETL	15.55	4.5	16	8	26	109
From the STA division to the ETL	18.9	12.8	16	0	53	104
From the STA division to the ZA	12.31	12.83	8.5	0	47	104
Angle (°)						
Frontal branch	27.93	12.22	28	0	60	97
Parietal branch	92.93	14.45	94	46	132	75
Main branch	109.21	11.08	109	75	140	109

ETL Eye Tragus Line, *STA* Superficial Temporal Artery

[a]*n* right and left sides

angle with the ETL ranged from 46–132° with a mean of 92.93 ± 14.45° and a median of 94°.

Supplementary branches

The number of supplementary branches ranged from 0–4 per STA. Thirty STA (26.32% of 114 cases) had one or more supplementary branch. Twenty-one (18.42%) supplementary branches came from the frontal branch and 9 (7.90%) from the parietal branch. The length of the supplementary branches ranged from 4–43 mm with a mean of 21.64 ± 12.02 mm and a median of 22.

Left/right differences

For 49 patients, the division point was observed at both sides. Mean differences on the ETL were − 1.9 ± 8.3 mm, ranged from − 25– + 18 mm with a median of − 1.8 mm. If the Euclidean distance between right and left measures is considered, it was 14.7 ± 9.8 mm, ranged from 1.5–38.9 mm with a median of 12.2 mm.

Mean representation of the STA anatomy, its division and its branches

The knowledge of the angles of the STA and its branches with the ETL and the distance between the tragus and the STA main branch allowed us to represent the mean anatomical representation of the STA anatomy and depict it on a scaled illustration of a profile face (Figs. 3, 4, 5). The ETL is represented on those figures as a graduated black line.

Figure 3 shows the scale representation of the exact point where the STA divides into two branches. Circles are right sided and triangles left sided measures. Colors are used to represent probability density area where the division can be found: 25%, 50% and 75% are contained in the red, green and blue areas, respectively. Only one case showed a division located below ETL.

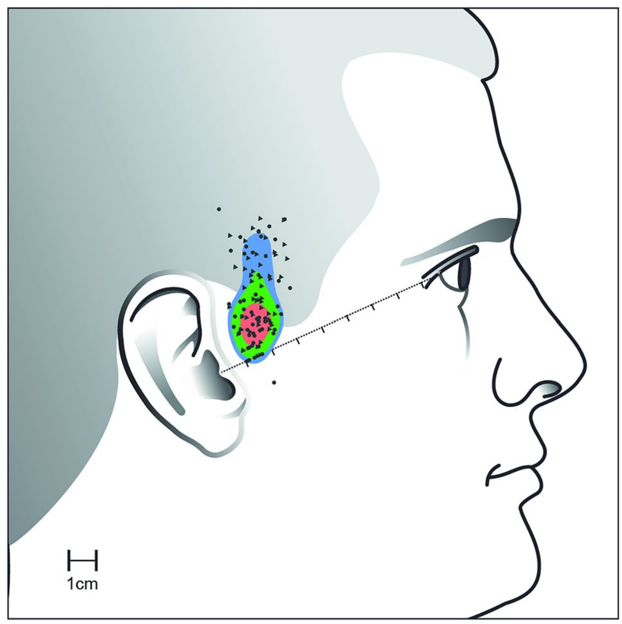

Fig. 3 Distribution of the STA division. Circles and triangles represent measures done on the right and left side, respectively. Red, green and blue areas represent the highest probability density areas containing 25%, 50% and 75% of observations, respectively. STA: superficial temporal artery

Figure 4 shows the distribution of the anatomy of the STA of every patients included in this study. The main, frontal and parietal branches are colored in blue, red and green, respectively. As the STA arises behind the mandibular

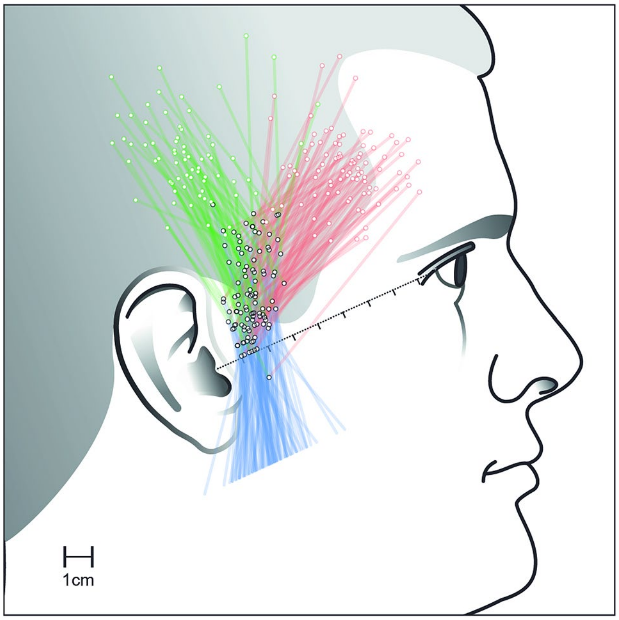

Fig. 4 Distribution of the anatomy of the STA and its branches of every patients included in this study. Main branch (blue), frontal branch (red), parietal branch (green). *STA* superficial temporal artery

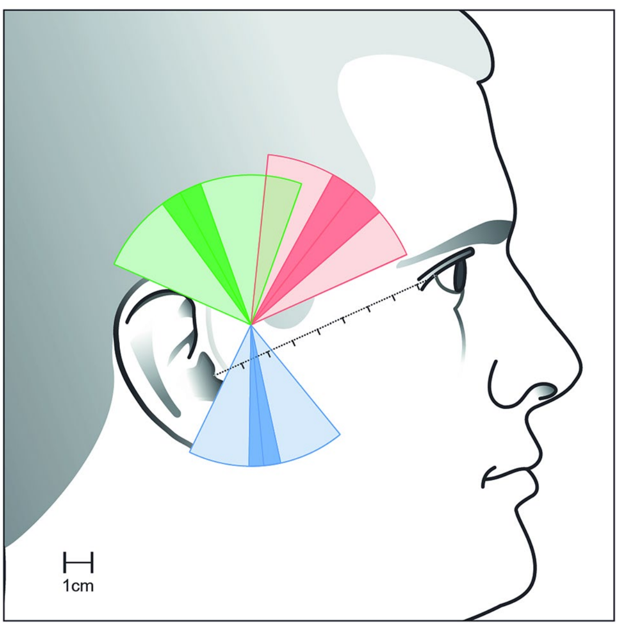

Fig. 5 Schematic representation of angles between the STA main branch (blue), the parietal (green) and frontal (red) branch. The division point was arbitrarily set at the mode of the distribution and the lengths of parietal and frontal branches correspond to the median length observed. For each branch, the four slices represent the four quartiles of the angle distribution, the thin line in the middle of the darker area being thus the median angle. *STA* superficial temporal artery

branch, it was not possible to illustrate it entirely. However, knowing the location of the STA division and the angle of the main branch with the ETL the main branch could be partially illustrated.

Knowing the median angles and lengths of the STA branches with the ETL and setting arbitrarily the division point at the mode of the distribution observed, it was possible to illustrate the mean anatomy of the STA and its branches (Fig. 5). Each branch was depicted as four slices that represent the four quartiles of the angle of distribution around the median angle depicted as a darker line. The same color code as in Fig. 4 was used.

Discussion

To the best of our knowledge, this is the first study with as many patients (57 patients, 114 STA). In previous publications, n ranged from 25–70 [4, 8, 11, 14, 15].

Our results showed that the STA division was located above the ZA in 61.54% of cases. For Kim et al. (Korea) [4], 82.6% were located above the ZA, 85.6% for Chen et al. (China) [15], 74.1% for Pinar and Govsa. (Turkey) [11], 80% for Mwachaka et al. (Kenya) [8] and 60% for Stock et al. (USA) [14] (Table 4). The differences between these studies may possibly be explained by the different ethnicities of the populations studied, our results (Europe, Belgium) being very close to the results of Stock et al. (USA).

The distance between the ZA and the STA was measured at 50.8 ± 20.9 mm by Mwachaka et al. (Kenya) [8], 21.7 ± 15.8 mm by Kim et al. (Korea) [4] and 12.31 ± 12.83 in our study. Although Mwachaka et al. (Kenya) [8] measured this distance to the midpoint of the ZA which is different from our study, these results show an anatomical variability of the STA possibly related to the origins of the studied population.

Unlike Mwachaka et al. [8], no trifurcation of the STA was find.

Pinar and Govsa [11] studied a line running from the tragus to the bony lateral canthus on 27 cadavers. This line is similar to the ETL developed in this study, however not exclusively based on external landmarks. In their study, the STA was located at 16.68 ± 3.35 mm in front of the tragus on a line running from the tragus to the bony lateral canthus. This is consistent with our study.

The bilateral topography of the STA bifurcation was not strictly comparable for each side. This observation should be considered when bilateral flap is needed, as point of division of one side cannot be strictly transposed to the other. This is consistent with the results of Manoli et al. which similarly concludes that the vascular pattern of one side cannot be transposed to the other [6].

Table 4 Comparison of previous publications studying the topography of the STA division regarding to the ZA

Topography of the STA division in relation to the ZA according to authors	Above (%)	Same level (%)	Below (%)	n^a
Present study (Belgium)	61.5	26.9	11.5	104
Kim et al. (Korea) [4]	82.6	3.8	9.6	70
Mwachaka et al. (Kenya) [8]	80	13.3	6.7	60
Pinar and Govsa. (Turkey) [11]	74.1	22.2	3.7	27
Stock et al. (USA) [14]	60	32	8	25
Tien-Hua et al. (China) [15]	85.6	3.8	22.2	52

STA Superficial Temporal Artery, *ZA* Zygomatic Arch

[a] *n* right and left sides

A drawback of our study is that the length and angle of the STA branches were measured as if the vessel was a straight line, thereby ignoring the sinuosity of the artery and considering the face as a flat plane. Furthermore, the exact point where the vessel stops on volume rendered reconstructions is not always clear. These are limits to our study.

Where previous articles used pictures (cadavers or 3D CT views) and drawings, this study provided a statistical representation of the wide variety of the anatomy of the STA and its two branches.

An external easy landmark to localize the STA and its division was defined in this article: the ETL, connecting the tragus and the corner of the eye. The ETL is easily usable in day-to-day practice and provides a quick landmark to find the STA main branch and its division point. This may help surgeons, clinicians and ultrasonographers to localize the STA, the main branch being located 15.55 ± 4.5 mm of front of the tragus on the ETL. The division of the STA was located below the ETL in 0.96% (1 case out of 104), the ETL can therefore be used as a landmark were this STA division is nearly always located above.

Author contributions JPH: Protocol/project development, Data collection or management, Data analysis, Manuscript writing/editing. BB: Data analysis, Manuscript writing/editing. FK: Manuscript writing/editing. MD: Protocol/project development, Data collection or management, Data analysis, Manuscript writing/editing.

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Code availability The R 3.5.2 software (R Foundation for Statistical Computing, Vienna, Austria, 2018) was used with ggplot2 package for the graphics and HDIntervals package for the determination of highest probability density areas. The images were obtained using an iCT Elite 256 Phillips CT (Phillips Healthcare, Cleveland, OH, USA).

Compliance with ethical standards

Conflict of interest The authors declare that they have no known competing financial or personal relationships that could be viewed as influencing the work reported in this paper.

Availability of data and material The authors declare that all data used in this study is fully available for reviewing and analysis.

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